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Pregnancy post-bariatric surgery: Improved outcomes with telephonic nutritional management program ☆

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ABSTRACT

Background: Pregnancies post-bariatric surgery are increasingly common. It is important to understand how to manage prenatal care in this high-risk population to optimize perinatal outcomes.
Objective: To determine among pregnancies post-bariatric surgery whether participation in a telephonic nutritional management program was associated with improved perinatal outcomes and nutritional adequacy.
Study design: Retrospective cohort study of pregnancies post-bariatric surgery from 2012 to 2018. Participation in a telephonic management program with nutritional counseling, monitoring and nutritional supplement adjustment. Modified Poisson Regression estimated the relative risk using propensity score methods to account for baseline differences between the patients who participated in the program and patients who did not.
Results: 1575 pregnancies occurred post-bariatric surgery, of which 1142 (72.5 % of pregnancies) participated in the telephonic nutritional management program. Participants in the program were less likely than non-participants to have a preterm birth (aRR 0.48, 95 % CI 0.35–0.67), preeclampsia (aRR 0.43, 95 % CI (0.27–0.69)), gestational hypertension (aRR 0.62, 95 % CI 0.41–0.93), and to have neonates admitted to a Level 2 or 3 (aRR 0.61, 95 % CI0.39–0.94; aRR 0.66, 95 % CI 0.45–0.97, respectively), after adjusting for the propensity score to account for baseline differences. Risk of cesarean delivery, gestational weight gain, glucose intolerance and birthweight did not differ by participation. Among 593 pregnancies with nutritional labs available, participants in the telephonic program were less likely to have nutritional inadequacy in late pregnancy (aRR 0.91, 95 % CI 0.88–0.94).
Conclusion: Participation in a telephonic nutritional management program post-bariatric surgery was associated with improved perinatal outcomes and nutritional adequacy.

Introduction

Almost one third of reproductive age women in the United States are obese [1]. Obese individuals who become pregnant are at increased risk of several perinatal complications. Bariatric surgery is an effective treatment for long-term weight loss [2] and reduces risk of obesity-related complications [3]. Over half of bariatric surgeries are performed on women of reproductive age [4], making it important to understand how to manage prenatal care in this high-risk population. Studies suggest an increased risk of preterm birth and small for gestational age infants in pregnancies post-bariatric surgery [5–7]. Micronutrient deficiencies are increased after bariatric surgery [8,9] and may have implications for the fetal environment [10]. Maternal nutritional deficiencies in folate, iron, and vitamin D, are linked with adverse perinatal outcomes [11]. Therefore, supplementation and surveillance for nutritional adequacy during pregnancy is recommended by clinical guidelines [12–14].

Nutritional management programs may improve perinatal outcomes among pregnant individuals post-bariatric surgery by serial monitoring for nutritional deficiencies and adjusting nutritional supplements as needed. This model of care is consistent with clinical guidelines for the care of pregnant individuals post-bariatric surgery, recommending a

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multidisciplinary care team and assessment of nutritional deficiencies every trimester [14,15]. Telehealth interventions have effectively supported self-care in a variety of populations including pregnant patients [16,17] and we hypothesize that outcome improvement may extend to pregnancies post-bariatric surgery.

We aimed to examine among a cohort of pregnancies occurring post-bariatric surgery whether participation in a telephonic nutritional management program improved perinatal outcomes using propensity score methods to estimate the effect of the telephonic nutritional management program on outcomes while adjusting for baseline differences between the patients who participated in the program and patients who did not. We then explored nutritional assessments performed and nutritional adequacy by participation in the telephonic nutritional management program.

Materials and methods

The study setting was an integrated health system from January 1, 2012 to December 31, 2018. During this time period, the health system provided comprehensive medical services through 16 delivery hospitals and over 40 outpatient clinics to over 3 million members located in a 14-county region. The demographic make-up of health system membership is well-representative of the population living in the geographical area served by this large, integrated health care delivery system, except that the health system population has slightly lower representation at the extremes of income [18]. The health system is vertically integrated and all care is provided in a closed system and captured in the electronic health record (EHR).

We identified 270,476 pregnancies with live births between 2012 and 2018. We then identified pregnancies occurring post-bariatric surgery pregnancy by searching for International Classification of Diseases (ICD) codes (ICD 10: O99.84, Z98.84, and K95 and ICD-9: 649.2, V45.86, 539) and procedure codes (43,644, 43,645, 43,770, 43,771, 43,772, 43,773, 43,774, 43,775, 43,842, 43,843, 43,844, 43,845, 43,846, 43,847, 43,848, 43,886, 43,887, 43,888, 44.68, 44.95), and an internal bariatric surgery case management data collection dashboard. We identified a cohort of 1575 post-bariatric surgery pregnancies among 1350 unique women from 2012 to 2018. Information on the timing and type of bariatric surgery was available for the subset of bariatric surgeries performed within the health system, this information was available for 689 pregnancies (43.7 %). The Research Determination Committee determined the project does not meet the regulatory definition of research involving human subjects since this study evaluated a program used in clinical practice and not an intervention done for research purpose.

Telephonic Nutritional Management Program

The Telephonic Nutritional Management Program is a standardized centralized program which offers supplemental care via telephone counseling to patients with high-risk pregnancies, including patients with a history of bariatric surgery, as an adjunct to their routine locally provided prenatal care. The program includes a call center providing inbound and outbound calls for education, home monitoring, and triage of pregnant patients with high-risk conditions. In addition to a team of registered nurses who perform telephonic management of patients requiring home monitoring for diabetes, hypertension, and risk of preterm birth, there are 4 registered dietitians (RDs) who offer telephone counseling on diet, physical activity, and medical nutrition therapy. Registered nurses are available to patients 24 h a day, 7 days a week, while the RDs are available to patients 8 a.m. to 8 p.m. 5 days a week. Care provided by the RD team includes a 45-min baseline consultation and follow-up nutritional counseling sessions by telephone, baseline and follow-up nutritional laboratory panels, and adjustment of nutritional supplements per protocol. The frequency of follow-up telephone sessions varies from once per trimester to once per month, depending on RD assessment of patient needs. The nutritional management protocol combines medical nutrition therapy and standard goals for nutrient and iron studies based on published reference ranges, including pregnancy-specific reference ranges when available. If other additional care is deemed potentially indicated, the RD team will contact patients' obstetric care provider and/or bariatric care provider. The RD team also conducts gestational diabetes screening per protocol, which for most patients post-bariatric surgery involves an alternative screening protocol (as described below).

The RD team follows a detailed algorithm for determining dosing recommendations for micronutrients and/or dietary changes based on comparison of patient's labs results and published pregnancy-specific reference ranges for the following: Vitamins A (retinyl, retinol, fish liver oil), B1, B12, D (Calcium citrate and D), zinc (zinc citrate or chelate), albumin (dietary protein), and iron (ferrous sulfate with Vitamin C if tolerated, intravenous iron dextran or iron sucrose if needed). This algorithm is reviewed regularly with health system bariatric medicine and maternal fetal medicine specialists and revised as needed.

Participation in the telephonic nutritional management program relies upon referral by a provider, as well as ongoing patient willingness to adhere to scheduled telehealth counseling sessions and monitoring of laboratory parameters. Usual care for non-participants in the telephonic nutritional management program at the health system is at the discretion of obstetric care providers. For this study, participation in the program was defined by at least one phone consultation with a registered dietician and one completed lab panel.

Outcomes

Preterm birth

Gestational age at delivery was extracted from the EHR. Preterm birth was defined as a live birth prior to 37 weeks' gestation.

Maternal hypertensive disorders

Pre-existing hypertension, gestational hypertension and preeclampsia/eclampsia were all based on ICD codes.

Glucose tolerance status

GDM was first identified with the standard two-step process based on two or more abnormal plasma glucose values of the four obtained during a 3-h 100 g oral glucose tolerance test according to the Carpenter-Coustan thresholds for GDM [19]. Within KPNC, some patients with risk factors for GDM are screened both early in pregnancy and at the standard 24–28 week gestational age, whereas others are screened only at 24–28 weeks, at the discretion of the obstetric clinician. We captured all GDM cases regardless of timing of diagnosis. Patients who were ineligible for glucose load based on surgical history or history of glucose-load intolerance received alternate testing based on our institution's protocol, given the lack of national guidance on optimal GDM screening in patients who cannot tolerate the standard 2-step testing [14,20]. Patients needing alternative testing were screened first with fasting plasma glucose plus hemoglobin A1c. If fasting plasma glucose was $\geq$ 95.0 mg/dl and hemoglobin A1c was $\geq$ 5.7 % and $<$ 6.5, patients were diagnosed as having GDM. If fasting glucose was $\geq$ 95.0 and hemoglobin A1c was normal at $<$ 5.7, patients went on to complete a week of home blood sugar monitoring four times daily to determine whether they met criteria for normal blood sugar or GDM.

Level 2 and 3 NICU admission was extracted from a clinical database that contains information obtained by manual chart review of all infants who have been admitted to the neonatal intensive care units [21].

Cesarean delivery was based on ICD codes available in the EHR.

Gestational weight gain (GWG)

Pre-pregnancy weight was defined as the last measured weight before conception up to 12 months prior to pregnancy (84.3 % of the analytic sample). If measured weight in the 12 months prior to pregnancy was not available, self-reported pre-pregnancy weight (14.0 % of analytic sample) or measured weight before 10 weeks of pregnancy (1.7 % of analytic sample) was used. Total GWG was categorized as below, within or above the 2009 Institute of Medicine (IOM) GWG recommended range [22].

Birthweight and infant size for gestational age

Infant birthweight was collected from the EHR. Small for gestational age (SGA), < 10th percentile, and large for gestational age (LGA), > 90th percentile, were based on the sex- and gestational-age-specific birthweight distributions of the 2017 US Natality files [23]. **Nutrient assessments**. We searched the EHR for laboratory measurements of key nutritional variables most likely to show deficiencies in pregnancy per prior literature review: Hemoglobin, Hematocrit, Ferritin, Hemoglobin A1c, Vitamin A, Vitamin B12, Calcium and Magnesium [8,24]. Of these, we analyzed five key variables: Hemoglobin, Ferritin, Vitamin A, and Vitamin B12 and Vitamin D, which are performed at multiple times during pregnancy to evaluate trends over time. We used standardized reference ranges of normal levels for key nutrients to determine whether nutritional inadequacy, defined as a value below the lower limit of the normal reference range, was present in any individual laboratory variable. We further analyzed nutritional status by determining whether inadequacy was present in early pregnancy (defined as the value of the 1st lab test performed ≤ 13 weeks gestation) and/or late pregnancy (defined as the value of the last lab test performed ≥ 26 weeks gestation). Finally, we created a composite nutritional status variable, with composite nutritional inadequacy defined as being inadequate in ≥ 1 of the 5 key variables.

Covariates used in propensity score

Maternal age, year of pregnancy and gestational week at first prenatal visit, parity, type of insurance coverage plan (private versus public) and neighborhood deprivation index (NDI) were obtained from the EHR system. Pre-pregnancy body mass index (BMI) was categorized using standard cut-points [25]. Maternal race/ethnicity was obtained from the EHR. Maternal race and ethnicity were categorized as non-Hispanic Black, Hispanic, Asian and Other vs. non-Hispanic White (reference group, hereafter referred to as White).

Statistical analysis

Descriptive statistics are reported overall and separately for nutritional management participant versus non-participant pregnancies. Means and standard deviations are used to describe continuous variables. Frequencies and percentages are used to describe categorical variables. Unadjusted comparisons between groups are based on t-tests or chi-squared tests, respectively.

We used modified Poisson regression to provide crude estimates of relative risks (RR) to estimate the effect of participation in the telephonic nutritional management program on dichotomous outcomes of interest [26].

We used propensity score methods to estimate the effect of the telephonic nutritional management program on outcomes while adjusting for baseline differences between the patients who participated in the program and women who did not. We first estimated propensity scores for participation in the telephonic nutritional management program using logistic regression with the following covariates that were measured before or at the time of participation in the program: maternal age at the date of conception (< 30, 30–34, 35–39 and 40 + years), race-ethnicity, pre-pregnancy BMI (normal weight, overweight, obese I, obese II, and obese III), parity (0,1, 2 +), insurance type (commercial insurance versus Medicaid status) at time of conception, first prenatal visit in the first trimester, NDI, and year of pregnancy. We then fit modified Poisson regression models for each dichotomous outcome of interest, including nutritional management program participation status as the exposure and the estimated propensity score as a continuous covariate. By conditioning on the propensity score, we are comparing patients who participated in the nutritional management program and patients who did not participate with comparable baseline characteristics. In a sensitivity analysis we further adjusted for time since surgery and type of surgery among the subset of women with that information available. We reported adjusted estimated relative risks (aRR) and corresponding 95 % confidence intervals that account for possible clustering [27] due to patients who had more than one pregnancy.

Results

Demographic and baseline characteristics of the 1575 pregnancies post-bariatric surgery identified in our cohort are described in Table 1. Pregnancies post-bariatric surgery occurred among individuals with a mean age of 33 years and pre-pregnancy BMI of 34.3 kg/m^2. Forty nine percent of the cohort were White, 32 % Hispanic, 11 % Black, and 4 % Asian. 1142 (72.5 %) of pregnancies were participants in the nutritional management program. When compared with non-participants, participants in the nutritional management program were slightly older, more likely to be nulliparous and more likely to start prenatal care in the first trimester. Participants were also less likely to be severely obese and less likely to be enrolled in public insurance (Table 1). On average, participating pregnancies had 4.4 contacts (S.D. ± 2.2) with the nutritional management program.

Participation was associated with a significantly decreased risk of preterm birth (aRR 0.48, 95 % CI 0.35–0.67), preeclampsia or gestational hypertension (aRR 0.43, 95 % CI 0.27–0.69 and RR 0.62, 95 % CI 0.41–0.93, respectively) and of having an infant admitted to a level 2 NICU (aRR 0.61, 95 % CI 0.39–0.94) or a level 3 NICU (aRR 0.66, 95 % CI 0.45–0.97) in the multivariable models. There was no significant difference in risk of cesarean delivery, GDM, GWG outside of the IOM guidelines, SGA nor LGA infants by participation status (Table 2).

Many pregnancies post-bariatric surgery had nutritional inadequacies, regardless of participation status, with inadequacies in Ferritin, Hemoglobin, and Vitamin B12 tending to increase as pregnancy progressed (Table 3). Participants were significantly more likely to undergo more frequent testing for key nutrients compared with non-participants ($p < 0.001$). Compared with non-participants, participants were less likely to be nutritionally inadequate in both early pregnancy and late pregnancy (Table 3). In multivariate models, participants were less likely than non-participants to be nutritionally inadequate in Ferritin (aRR 0.78, 95 % CI: 0.68–0.91), Hemoglobin (aRR 0.67, 95 % CI: 0.59–0.76), and Vitamin B12 (aRR 0.69, 95 % CI: 0.57–0.84) in late pregnancy. Fewer participants (89.5 %) than non-participants (100.0 %) showed a composite nutritional inadequacy in late pregnancy in the multivariate model (aRR 0.91, 95 % CI: 0.88–0.94, Table 3).

A sensitivity analysis among the 689 pregnancies with information on timing and type of surgery found that after including these variables in the propensity score adjusted analysis results were similar for preterm birth 0.46 (0.26–0.81) and NICU admissions 0.54 (0.33–0.87) but not for preeclampsia 0.57 (0.20–1.61) or gestational hypertension 1.21 (0.51–2.87) (See Supplemental Table 1).

Discussion

Principal findings

Telephonic nutritional management of pregnancies post-bariatric surgery was associated with a decreased risk of preterm birth, maternal hypertensive disorders of pregnancy (including gestational hypertension and preeclampsia) and having an infant requiring a Level 2 or 3 NICU admission. There were no significant differences between participants and non-participants in rate of cesarean delivery, GWG and

Table 1
Baseline characteristics of cohort overall and by telephonic nutritional management program participation.

		Overall Cohort	Participant N = 1142	Non-Participant N = 433	P-value
		Mean (± SD) or N (%)			
Maternal Age		33.0 (± 4.7)	33.2 (± 4.7)	32.7 (± 4.8)	0.072
	< 30	367 (23.3)	262 (22.9)	105 (24.3)	0.783
	30–34	594 (37.7)	430 (37.7)	164 (37.9)	
	35–39	496 (31.5)	360 (31.5)	136 (31.4)	
	> = 40	118 (7.5)	90 (7.9)	28 (6.5)	
Race/Ethnicity	White	766 (48.6)	570 (49.9)	196 (45.3)	0.514
	Black	165 (10.5)	114 (10.0)	51 (11.8)	
	Asian/PI	69 (4.4)	48 (4.2)	21 (4.9)	
	Hispanic	507 (32.2)	360 (31.5)	147 (34.0)	
	Other/Unknown	68 (4.3)	50 (4.4)	18 (4.2)	
Neighborhood Deprivation Index*	Quarter 1 (− 2.4, − 0.8)	207 (13.1)	150 (13.1)	57 (13.2)	0.316
	Quarter 2 (− 0.8, − 0.3)	393 (25.0)	290 (25.4)	103 (23.8)	
	Quarter 3 (− 0.3, 0.3)	435 (27.6)	322 (28.2)	113 (26.1)	
	Quarter 4 (0.3, 4.8)	534 (33.9)	374 (32.8)	160 (37.0)	
	Missing/Unknown	6 (0.4)	6 (0.5)	0 (0.0)	
Medicaid Insurance	No	1382 (87.8)	1018 (89.1)	364 (84.1)	0.002
	Yes	162 (10.3)	109 (9.5)	53 (12.2)	
	Missing/Unknown	31 (2.0)	15 (1.3)	16 (3.7)	
Parity	0	560 (35.6)	432 (37.8)	128 (29.6)	0.004
	1	537 (34.1)	390 (34.2)	147 (34.0)	
	2 +	472 (30.0)	316 (27.7)	156 (36.0)	
	Missing/Unknown	6 (0.4)	4 (0.4)	2 (0.5)	
Pre-pregnancy BMI		34.3 (± 7.4)	33.9 (± 7.0)	35.4 (± 8.3)	< .001
	Normal Weight (18.5–24.9)	103 (6.5)	76 (6.7)	27 (6.2)	< .001
	Overweight (25.0–29.9)	371 (23.6)	274 (24.0)	97 (22.4)	
	Obese Class I (30.0–34.9)	437 (27.8)	334 (29.3)	103 (23.8)	
	Obese Class II (35.0–39.9)	320 (20.3)	243 (21.3)	77 (17.8)	
	Obese Class III (40 +)	307 (19.5)	197 (17.3)	110 (25.4)	
	Missing/Unknown	37 (2.4)	18 (1.6)	19 (4.4)	
Time Starting Prenatal Care	PNC started in 1st trimester	1430 (90.8)	1059 (92.7)	371 (85.7)	< .001
	No PNC** or PNC started after 1st trimester	145 (9.2)	83 (7.3)	62 (14.3)	
Year of Pregnancy	2011	122 (7.8)	81 (7.1)	41 (9.5)	0.014
	2012	202 (12.8)	159 (13.9)	43 (9.9)	
	2013	197 (12.5)	150 (13.1)	47 (10.9)	
	2014	224 (14.2)	158 (13.8)	66 (15.2)	
	2015	247 (15.7)	182 (15.9)	65 (15.0)	
	2016	249 (15.8)	174 (15.2)	75 (17.3)	
	2017	269 (17.1)	201 (17.6)	68 (15.7)	
	2018	65 (4.1)	37 (3.2)	28 (6.5)	
Pre-existing HTN	Yes	186 (11.8)	130 (11.4)	56 (12.9)	0.395
Pre-existing T2DM	Yes	129 (9.2)	40 (10.2)	89 (8.8)	0.428
History of preterm birth	Yes	64 (4.1)	44 (3.9)	20 (4.6)	0.002
	No	1163 (73.8)	870 (76.2)	293 (67.8)	
	Missing/Unknown	348 (22.1)	228 (20.0)	120 (27.7)	
Time of pregnancy after Bariatric surgery***	< 2 Years	287 (41.7)	246 (44.2)	41 (30.8)	0.001
	2–4 Years	309 (44.8)	246 (44.2)	63 (47.4)	
	> = 5 Years	93 (13.5)	64 (11.5)	29 (21.8)	
Type of Bariatric surgery***	Gastric Band	23 (3.3)	11 (2.0)	12 (9.0)	< .001
	Roux-En-Y Gastric Bypass	363 (52.7)	299 (53.8)	64 (48.1)	
	Sleeve	303 (44.0)	246 (44.2)	57 (42.9)	

*Quartiles of Neighborhood Deprivation Index (NDI) was based on the distribution of NDI in a general population of pregnant women who delivered from 2012 to 2018.
**PNC = Prenatal Care.
*** Only available for 689 pregnancies where the bariatric surgery was performed.

size for gestational age. Participants in the telephonic nutritional management program had more laboratory assessments of nutritional status and were less likely to have nutritional inadequacy in late pregnancy compared with non-participants.

Results

A recent systematic review and meta-analyses demonstrated an increased risk of adverse perinatal outcomes including preterm birth, NICU admission, SGA, and perinatal death after a bariatric surgery, suggesting a need for enhanced nutritional monitoring in these pregnancies [28]. A small non-randomized study of 61 pregnancies post-bariatric surgery prospectively compared a group with a nutritional intervention to a group without surgery and a retrospective control post-bariatric surgery group, and found personalized nutritional counseling care post-bariatric surgery improved nutrient intake of mothers and may contribute to higher birth weight of offspring [29]. However, one study found that less than one fourth of patients receive nutritional counseling in pregnancy post-bariatric surgery [30], indicating a need for innovative strategies to bridge the current gap in care. The COVID-19 pandemic necessitated a rapid shift to telemedicine, and we expect that telemedicine will be an increasingly standard element of care delivery [31]. Telephonic nutritional management has been shown to be effective in management of perinatal conditions including gestational diabetes [16,17] and hypertensive disorders of pregnancy [32]. Our study suggests that participation in a telephone nutritional management program for pregnant patients post-bariatric surgery is associated with a reduced risk of several adverse perinatal outcomes. We also found that

Table 2
Relative risks (RRs) and 95 % confidence intervals (CIs) for perinatal outcomes associated with telephonic nutritional management program participation versus non-participation.

Perinatal outcome	Participant N = 1142	Non-participant N = 433	Relative risks Crude	Adjusted*
Preterm Birth	87 (7.6)	68 (15.7)	**0.49 (0.36–0.66)**	**0.48 (0.35–0.67)**
Cesarean Section	436 (38.2)	162 (37.4)	1.02 (0.88–1.18)	1.04 (0.89–1.21)
Pre-eclampsia	41 (3.6)	30 (6.9)	**0.49 (0.31–0.78)**	**0.43 (0.27–0.69)**
Gestational Hypertension	64 (5.6)	35 (8.1)	**0.65 (0.44–0.97)**	**0.62 (0.41–0.93)**
GDM or IFG**	255 (22.3)	108 (24.9)	0.91 (0.75–1.09)	1.00 (0.82–1.22)
Admission to NICU Level 2	57 (5.0)	30 (6.9)	0.69 (0.45–1.06)	**0.61 (0.39–0.94)**
Admission to NICU Level 3	75 (6.6)	44 (10.2)	**0.63 (0.44–0.90)**	**0.66 (0.45–0.97)**
Exceed IOM Guidelines	733 (64.1)	250 (57.7)	1.03 (0.96–1.10)	1.00 (0.94–1.07)
Below IOM Guidelines	214 (18.7)	93 (21.5)	0.96 (0.81–1.12)	0.97 (0.82–1.14)
LGA	117 (10.3)	50 (11.6)	0.91 (0.66–1.25)	1.03 (0.74–1.44)
SGA	132 (11.6)	40 (9.2)	1.23 (0.87–1.75)	1.18 (0.82–1.72)

*Adjusted for propensity score for participating in the telephonic nutritional management program.
**IFG = Impaired Fasting Glucose.

compared with non-participants, participants in a telephonic nutrition program had more laboratory measurements of nutritional status and were less likely to be nutritionally inadequate in serum levels of Ferritin, Hemoglobin and Vitamin B12 in late pregnancy, however, we observed no difference in birthweight.

A small prospective study of pregnant women post-bariatric surgery found deficiencies in micronutrients were common and that supplementation partially improved the low levels of micronutrients especially for vitamins A and B-1 and albumin [33]. Our study is consistent with prior studies showing a high prevalence of anemia in this population, as well as maternal nutritional deficiencies in vitamins A, D, B1, B9, and B12 [7,24,33]. Correcting these micronutrient deficiencies may mitigate risk of adverse perinatal outcomes since micronutrients influence metabolic activities that support tissue growth and functioning in the maternal patient and developing fetus [34].

The innovation of telephonic nutritional management includes increased accessibility for busy patients, more frequent contact with a multidisciplinary team, and increased frequency of laboratory testing for key nutrients, all of which may enhance adherence to supplementation. This model of care is consistent with expert recommendations for clinical care of pregnant individuals post-bariatric surgery, including a multidisciplinary care team with assessment of nutritional deficiencies every trimester [15]. The standardized and centralized nature of the care model in our study, permits strict protocol development and consistent expertise of registered dieticians who have honed skills in managing nutritional needs specific to pregnancies post-bariatric surgery. While this kind of service can be provided in an in-person contact, there is potential benefit to concentrating this specialty care provision in the hands of a smaller number of expert practitioners enabling centralization across a geographic area [35,36].

Unfortunately, we lacked information on the interval between bariatric surgery and pregnancy on about half of our cohort. Prior studies examining the impact of interval from surgery to conception on perinatal outcomes are mixed, with Parent et al. finding an increased risk of PTB, NICU admission and SGA with shorter surgery to conception interval < 24 months [37]and Johansson et al. [6] identifying increased risk of SGA associated with longer surgery to conception interval > 1.8 years. Other studies have found no association between time interval from surgery to conception and adverse perinatal outcomes [38–40]. While limited data suggest that a very short surgery to conception interval following sleeve gastrectomy (< 6 months) is associated with increased risk of SGA [41], more data are needed to guide clinical recommendations on optimal surgery to conception interval. When we accounted for the time interval among the subset with the information available, our results were generally consistent, except the reduced risk of preeclampsia was no longer significant. This warrants further study.

Clinical implications

We are unaware of any prior studies that have evaluated the impact of telehealth models of prenatal care post-bariatric surgery in relation to perinatal outcomes. However, a prior study demonstrated that participation of GDM patients in a telephonic nutritional management program was associated with improved perinatal outcomes, including a decreased risk of macrosomia [17]. Care delivery characteristics of both that GDM telephonic nutritional management program and the post-bariatric surgery program include standardized centralized telephonic contact that includes nutritional counseling, medical nutrition therapy, and adjustment of medications (hypoglycemic agents for GDM) or nutritional supplements (for post-bariatric surgery). Therefore, we hypothesize that outcome improvement seen with this method of standardized centralized care delivery in these high risk pregnant populations may extend to other obstetric and/or medical conditions

Table 3
Nutritional assessments and adequacy by telephonic nutritional program participation.

Nutritional variable (# with this variable available)	Early pregnancy Participant % inadequate	Early pregnancy Non-participant % inadequate	Late pregnancy Participant % inadequate	Late pregnancy Non-participant % inadequate	Adjusted relative risk for nutritional inadequacy in late pregnancy*
Ferritin (n = 834)	48.9	64.4	60.3	78.0	0.78 (0.68–0.91)
Hemoglobin (n = 1413)	26.5	27.2	34.1	52.9	0.67 (0.59–0.76)
Vitamin A (n = 676)	49.1	60.7	52.0	53.6	1.06 (0.73–1.53)
Vitamin B12 (n = 722)	43.2	63.4	43.6	75.6	0.69 (0.57–0.84)
Vitamin D (n = 682)	14.0	28.2	5.4	10.3	0.79 (0.35–1.80)
Composite nutritional status** (N = 593)	85.1	90.9	89.5	100.0	0.91 (0.88–0.94)

*Adjusted for propensity score for participating in the telephonic nutritional management program and early pregnancy nutritional adequacy. The reference group is non-participants.
**Composite nutritional status variable is defined as being inadequate in any of the 5 labs (Hemoglobin, Ferritin, Vitamin A, and Vitamin B12 and Vitamin D).
*** Nutritional variable (*participant N, non-participant N*): Ferritin (*N = 775, N = 59*), Hemoglobin (*N = 1056, N = 357*), Vitamin A (*N = 648, N = 28),* Vitamin B12 (*N = 681, N = 41*), Vitamin D (*N = 643, N = 39*), Composite nutritional status (*N = 571, N = 22*).

encountered in pregnant patients.

Strengths and limitations

Strengths of our study include a large racially/ethnically diverse study population, and the ability to abstract laboratory measures of key nutrients and perinatal outcomes from the EHR in a cohort of pregnancies post bariatric surgery. Another strength of our study was that the telehealth nutritional intervention was delivered by trained registered nurses and dieticians. The study also has important limitations. First, the patient decision to not-participate in the nutritional program may reflect differences that we were unable to adequately balance out through propensity score matching. However, our propensity scores used a wide range of variables available in the EHR, and the distribution of the propensity scores of the two groups were comparable and appropriate for covariate adjustment [42]. Further exploration is needed to clarify factors associated with patients' motivation for engaging in the nutritional program. The assessment of nutritional inadequacy is limited by the laboratory variables available in the EHR, there may be other micronutrients that contribute to health outcomes. We also lacked information on timing and type of surgery for more than half of pregnancies in this study, therefore we were unable to fully explore whether the impact varied by these factors, but a sensitivity analysis suggested similar results independent of timing and type of surgery.

Conclusions

In sum, our findings indicate that participation in standardized telephonic nutritional management for patients with pregnancies following bariatric surgery may improve perinatal outcomes and nutritional adequacy in late pregnancy. Future directions include identifying factors associated with participation in the telehealth nutritional program, and exploring what program-level or patient-level factors, including type of bariatric surgery, decrease the likelihood of adverse outcomes to increase our understanding of the optimal care for these high-risk pregnancies.

Ethical Statement

The Research Determination Committee determined the project does not meet the regulatory definition of research involving human subjects.

Conflict of Interest

The authors report no conflict of interest.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.orcp.2023.02.006.

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